ART. 5. INDIVIDUAL AND GEOGRAPHIC VARIATION IN *BLARINA BREVICAUDA* FROM PENNSYLVANIA

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INTRODUCTION

Within the Commonwealth of Pennsylvania and in most of the northeastern states, the short-tailed shrew, *Blarina brevicauda,* is one of the most abundant small mammals encountered by collectors. This semi-fossorial insectivore is the cosmopolite of Pennsylvania mammals, being found in practically every terrestrial habitat throughout the area. Local conditions may affect the population density within a given area, but they present no major barriers to genetic interchange. In effect, these animals comprise one continuous interbreeding population throughout the area. This study is an attempt to analyze the extent of variation present in a dense and relatively stable population, as seen in *Blarina brevicauda* from Pennsylvania.

As one of the outgrowths of the Pennsylvania Mammal Survey the collection of Carnegie Museum contains slightly over 3000 specimens of the short-tailed shrew, preserved as study skins accompanied by skulls or as skeletal material without skins. Of this collection, 1193 specimens were examined during the course of the study. The remainder of the specimens were either scattered in insufficient numbers throughout the state, or for one reason or another, primarily age and damage in trapping, were not used. Of the state's 67 counties, 23 were represented by a sufficient amount of material to allow the application of limited statistical analysis.

Data on variation are drawn almost entirely from external and cranial characters. Variation of pelage in *Blarina* is too subtle to permit any objective study of it within the area.

I wish to extend my thanks to Dr. J. Kenneth Doutt, Curator of Mammals, Carnegie Museum, not only for the unrestricted use of the mammal collection and its records, but also for his patient and understanding advice and criticism, without which this project would have suffered greatly. I also wish to thank Miss Caroline A. Heppenstall, Assistant Curator of Mammals, Dr. Dana P. Snyder, Research Mammalogist, C. J. Morrow, Jr., Staff Illustrator, and the many others who have aided me immeasurably.

The material on which this study is based is a part of the mammal collection of Carnegie Museum. Most of the specimens were collected by the Pennsylvania Mammal Survey—Pittman-Robertson Projects conducted under the Federal Aid to Wildlife Restoration Act of 1937. Final reports have been published on each project (Richmond and Rosland [sic], 1949; Grimm and Roberts, 1950; Roslund, 1951; Gifford and Whitebread, 1951; Grimm and Whitebread, 1952; Roberts and Early, 1952).

VARIATION WITHIN A SINGLE POPULATION

The study of subspeciation in any form of animal life can not be ap-

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proached intelligently without first gaining an idea of the extent of individual variation within one interbreeding population.

This section is based on a study of 121 skulls of *Blarina brevicauda* collected at East Springfield, Erie Co., Pa., from October 24, 1947 to November 15, 1947, by W. W. Goodpaster. They were selected because they comprised the largest group available from a single locality and, so far as collecting techniques were concerned, the group was one of the most homogeneous. The measuring and sexing of the collection in the field was handled by one man. Specimens were all taken in "Museum special" snap traps.

The purpose was to ascertain, as far as possible, the amount of variation due to age, sex, and individual variation present in the population. Nine of the specimens could not be aged because damaged by traps, and measurements for these nine were included only in those instances where age was not a problem. The field measurements taken were the standard—total length, length of tail, hind foot, and ear measured to the nearest millimeter. Measurements were taken by the collector with a pair of calipers, read against a steel rule. The specimens were weighed to the nearest half gram on Ohaus scales. Skull measurements (Fig. 1), recorded to the nearest tenth of a millimeter, were taken by myself with the aid of a binocular dissecting microscope and vernier calipers.

The skulls were aged by a system based on morphological changes in the skull itself, especially degree of suture closure and relative development of the sagittal and lambdoid crests. This is a modification of the methods outlined in Doutt (1942). Tooth-wear was not used as a criterion of age in this case because it was felt to be too easily influenced by environmental effects, diet, habitat, etc. Specimens were found which had advanced tooth-wear, yet which appeared younger than other specimens showing only moderate wear on the teeth but a greater development of skull crests and other signs of age.

Pearson (1945), aging samples of *Blarina*, used tooth-wear as the criterion and obtained satisfactory results. Pruitt (1954) likewise has found tooth-wear a satisfactory criterion for aging *Sorex cinereus*. It is my feeling that both systems of arriving at a relative age (that is, tooth-wear and suture closure) would work equally well when applied to a single sample. However, in comparing samples from widely scattered localities, a system based on a single criterion, especially one so directly affected by the environment as tooth-wear, may lead to the establishment of relative age scales which would not be comparable between samples. Rate of suture closure, being relatively independent of direct environmental influence, would seem to be the better criterion of age when geographically scattered samples are to be compared.

The general pattern of changes due to increasing age is as follows. In the earliest stage examined, the lambdoid, sagittal and otic sutures appear to be completely open. (As here used, the term "otic suture" designates that suture which bounds the otic complex where it contacts the parietal dorsally and the squamosal anteriorly.) The naso-frontal suture is in the process of closing. The sagittal suture soon begins to close at its anterior

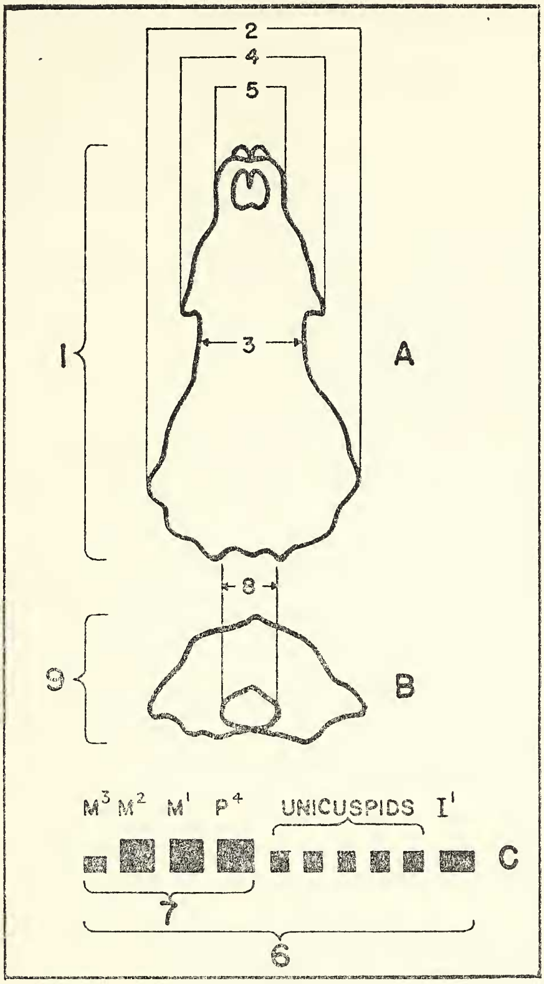

Fig. 1. Diagrammatic views of skull and upper tooth row of *Blarina brevicauda* showing measurements employed. A, dorsal view of skull; B, posterior view of skull; C, semi-diagrammatic view, left side of upper tooth row

Definition of measurements: 1. *Total length of skull.* Anterior surface of incisors to most posterior surface of occipital condyles. 2. *Cranial breadth.* Greatest transverse diameter of skull. 3. *Interorbital width.* Least diameter between orbits. 4. *Maxillary breadth.* Transverse diameter of skull across maxillary processes. 5. *Rostral width.* Greatest external diameter, measured across external nares. 6. *Length of upper tooth row.* From anterior surface of first incisor to posterior surface of last molar. 7. *Length of upper molariform tooth row.* From anterior surface of last premolar to posterior surface of last molar. 8. *Width of foramen magnum.* Greatest transverse diameter. 9. *Occipital height.* Vertical distance from lambda to external basioccipital fossa.

end and forms almost immediately that part of the sagittal crest from which M. levator labii superioris proprius (Ärnbäck-Christie-Linde, 1907) originates. At this stage the posterior half of the sagittal suture remains open and the remainder of the crest undeveloped.

Next, the portion of the otic suture which runs from the zygomatic process of the squamosal to the tympanic region on the ventral surface of the skull begins to fuse. At about the same time the lambdoid suture begins to fuse sporadically along its lateral aspects, and occasionally fusion is also found at the lambda. The lambdoid and sagittal crests begin to form by a bony thickening of the areas involved before the sutures fuse to any extent. The sagittal crest continues to form while further closing of the sagittal suture appears to be arrested temporarily. Fusion continues in an erratic fashion on the lambdoid suture. The lambdoid crest continues to develop not only by thickening at the suture but also by a bony extension which appears to grow anteriorly over the parietals for a short distance. This is especially marked at the lambda, diminishing laterally, and it makes the exact status of the degree of closure of the lambdoid suture hard to ascertain in those cases in which it is pronounced. The otic suture, aside from the seemingly early closure of its ventral one-third, closes erratically, but lags slightly behind the lambdoid suture. The naso-frontal suture continues to close at a slow rate during this process and in the later stages closure is complete. The last suture to close completely is the sagittal. While, as noted above, its anterior portion closes very early, the posterior half seems to be the last of the cranial sutures to coalesce.

During the later aspects of suture closure, the muscular attachments, crests, ridges, etc., become more pronounced and the cranium takes on a flat appearance. The rostrum appears to widen with age, this impression being intensified by the rotation of the first incisors in older individuals. In Fig. 2, A shows a lateral view of the three upper incisors as they appear in a relatively young animal. The shaded parts of the teeth represent the pigmented areas. From a dorsal view, Fig. 2, B, the first incisors can readily be seen extending the profile out to a point. In Fig. 3, A, the condition in old age is seen. The entire tooth (incisor 1) rotates down to compensate for increasing wear and to maintain an efficient cutting edge. As the rotation increases, the bone covering the anterior margin of the root seemingly erodes back and the anterior portion of the root of the first incisor is exposed. This condition has been recorded for *Sorex* by Warren (1942) and is apparently characteristic of the family. From a dorsal view, Fig. 3, B, it will be seen that the first incisors, having swung to a nearly vertical position, no longer enter as conspicuously into the dorsal profile of the skull. This abruptly truncated appearance tends to give an illusion of width to the rostrum, which apparently (Table 1) does not widen appreciably with age.

To establish a basis for classification by age, each suture was assigned a number which coincided with its degree of closure. The sutures that were used for determining relative age were the naso-frontal, sagittal, lambdoid, and the otic. All other cranial sutures closed at a very early

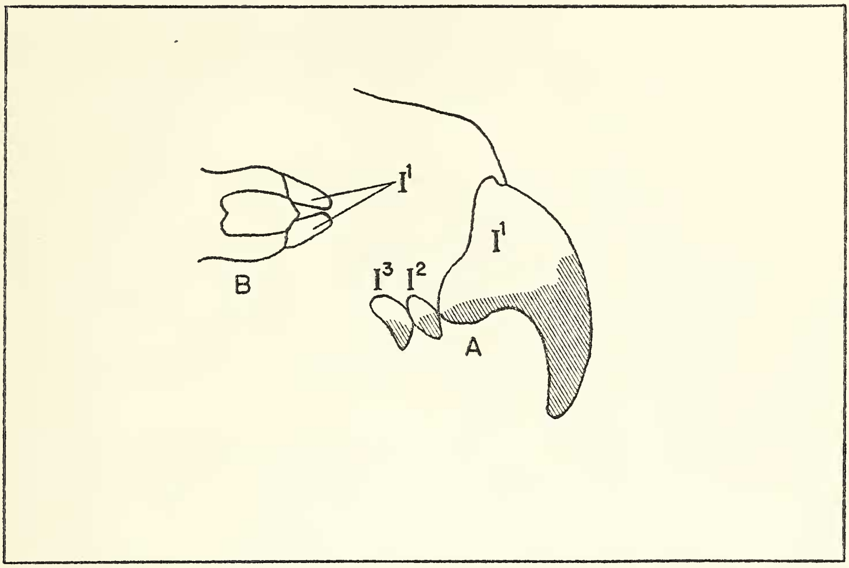

Fig. 2. Lateral view (A) and dorsal view (B) of anterior portion of skull of a relatively young *Blarina brevicauda*. Shaded portion indicates pigmentation

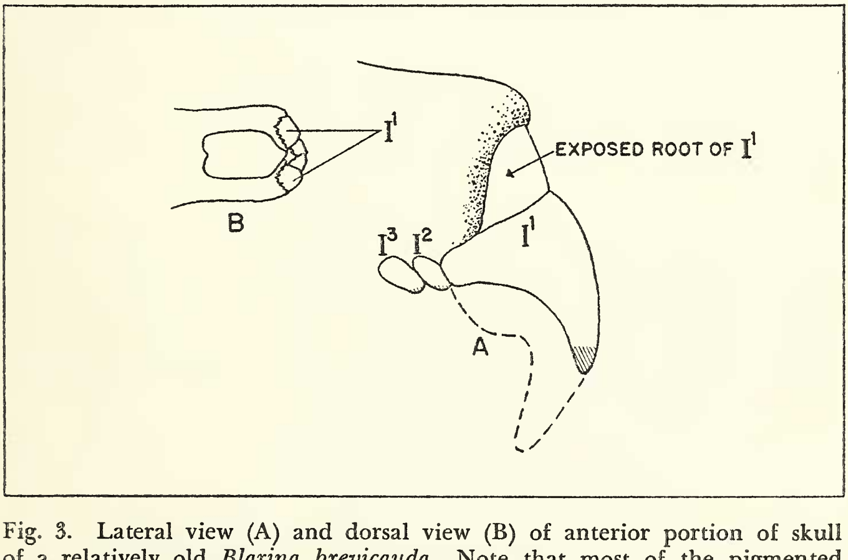

Fig. 3. Lateral view (A) and dorsal view (B) of anterior portion of skull of a relatively old *Blarina brevicauda*. Note that most of the pigmented area has been worn away. Dashed line indicates the original boundary of incisor

age and were of no help in determination of age. Numbers were assigned as follows: 1, open; 2, less than half-closed; 3, more than half-closed; 4, closed. Numbers were also given the sagittal and lambdoid crests, based on their state of development: 1, not present; 2, forming; 3, present; 4, prominent.

The numbers assigned to the four sutures and two crests used for each skull were then added together, and the resulting number was the assigned age class of that animal. The skulls could then be arranged in 18 relative age classes, having a theoretical range from 6 to 24. This was more than sufficient to include all of the 112 specimens in the sample. The actual range obtained was from 9 (youngest) to 22 (oldest). None of the age classes showed any significant difference in sex ratio. This would seem to indicate that the rate of suture closure and crest formation is the same in both sexes, assuming that a given relative age class represents the same chronological age in both sexes.

Aging by suture closure is subject to some error, and one is often in doubt as to which number to assign a given suture; furthermore, the order of suture closure is not constant in all cases, so an error of plus or minus one age class could be expected. The skulls were therefore arbitrarily lumped into groups having a range of two age classes. Age classes 17 through 22 were lumped into one group, because at 17 or beyond the animals had obviously reached old age and further development was practically nil; this afforded a group of sufficient size to be treated statistically.

In Table 1 the means of the youngest and the oldest groups (sexes combined) are compared. Length of upper molariform tooth row, length of upper tooth row, and total length of skull increase up to age group 15-16 and then decrease with age, because of tooth-wear, so in these three dimensions, comparisons were between the youngest and the oldest group in which an increase was noted. A significant increase from youngest to oldest was noted in all except three dimensions—tail length, interorbital breadth and length of upper tooth row. However, in each case the mean of the younger group was more than 90% of the mean of the older group.

Since the differences in size between the oldest and youngest specimens were quite small, a further lumping of age classes seemed desirable. It was found that the means of all the age classes for the measurements, weight and maxillary breadth (two dimensions showing highly significant differences between young and old) could be arranged in three major age groups. Within each group, the difference between the means of component age classes was not significant and between each two groups the difference was either significant or bordering thereon.

Group	*Age classes*
1:	9-10
2:	11-16
3:	17-22

In any comparison between samples collected at different times of the year, age changes should be taken into account, since the age composition of a population of *Blarina* varies markedly from season to season (Pearson,

TABLE 1. VARIATION DUE TO AGE IN A SAMPLE OF *BLARINA BREVICAUDA* (SEXES COMBINED) FROM EAST SPRINGFIELD, ERIE CO., PA. (See explanation, p. 50, 52)

Measurement	Age classes	Number of specimens	Mean	Difference (youngest to oldest)	t score	$100 \frac{\text{mean of youngest}}{\text{mean of oldest}}$
Total length	17-22	19	119.1	+4.7	2.68*	96.0%
	9-10	16	114.4			
Length of tail	17-22	19	25.6	+0.1	0.18	99.6%
	9-10	16	25.5			
Weight	17-22	19	17.42	+1.67	4.43†	90.4%
	9-10	16	15.75			
Total length of skull	15-16	11	23.7	+0.5	3.03†	97.8%
	9-10	16	23.2			
Cranial breadth	17-22	17	12.7	+0.5	4.60†	96.0%
	9-10	14	12.2			
Interorbital breadth	17-22	19	5.98	+0.12	1.69	98.3%
	9-10	16	5.86			
Maxillary breadth	17-22	19	7.94	+0.26	3.16†	96.7%
	9-10	16	7.68			
Rostral breadth	17-22	19	3.16	+0.08	2.28*	97.4%
	9-10	16	3.08			
Length of tooth row	15-16	18	10.87	+0.12	1.29	98.8%
	9-10	16	10.75			
Length of upper molariform row	15-16	18	6.30	+0.12	2.36*	98.0%
	9-10	16	6.18			
Width, foramen magnum	17-22	17	3.33	+0.15	2.83†	95.4%
	9-10	16	3.18			
Occipital height	17-22	19	6.66	+0.14	2.25*	97.8%
	9-10	15	6.52			

* Probability between 5% and 1% level † Probability beyond 1% level

(The following abbreviations and symbols have been used in various tables: d=*Mean* ♂ *minus mean* ♀. M=*Mean* ± σ_m. N=*Number of specimens in sample.* R=*Range.* V=*Coefficient of variation.* σ=*Standard deviation.)*

1945). However, in *Blarina brevicauda* a detailed breakdown of age does not appear necessary for studies of geographic variation, and produces no significant refinement beyond the three major groups outlined above, composed of relatively young, adult, and relatively old individuals.

There is a rapid growth rate in nestling *Blarina* (Hamilton, 1943; Pearson, 1945). Shrews attain essentially adult size before they become susceptible to trapping, and hence the younger animals in collections are, in many characters, indistinguishable from adults. However, in order to show the maximum variation to be expected, the three age groups are combined in computing coefficients of variation. It will be seen that the external measurements, in most cases exhibit higher coefficients than do the cranial measurements (Table 1).

Sexual differences in the population studied were not apparent visually, but could be demonstrated statistically (Table 2). In every case the males averaged slightly larger than the females.

A small, but significant, degree of sexual difference could be demonstrated in weight. Weight showed the greatest increase with age, 1.67 grams from the youngest to oldest (Table 1) with a relatively high coefficient of variation, males, 10.25; females, 11.51. Weight, subject to such factors as age, sex, reproductive status, daily fluctuations, diet, general health of the animal, season, and time elapsed since capture, would appear to be one of the least dependable of all measurements.

The ear measurement, although apparently unaffected by age or sex, is also an unreliable measurement in *Blarina*. In 121 specimens the observed range for this measurement was only two millimeters (6-8 mm.). It is not an easy measurement to take with any degree of consistency, and the error of measurement might easily equal the actual range of variation. In other words, the unit of measurement, to the nearest millimeter, is too coarse to demonstrate the true extent of variation present.

Length of tail shows no significant increase due to age (Table 1) and a slight, but significant sexual difference (Table 2). However, since individual variation is high ($V = 6.78$ in males; 5.29 in females) and could easily be affected by injury, length of tail is not a particularly desirable character for use in the study of geographic variation.

Of the five external measurements, total length had one of the lowest coefficients of variation (males, 3.66; females, 4.73). It was influenced only slightly by sex and showed a significant increase of 4.7 millimeters due to growth. The fact that the measuring was done by only one person in this case may have been responsible for the relatively low coefficient of variation.

Length of hind foot would seem to be one of the most dependable external measurements available. Compared with the other external measurements it has a low coefficient of variation (males, 4.63; females, 4.61); it is not affected by age, and the sexual difference (Table 1) would cancel out in comparing samples of approximately equal sex composition. However, as brought out below, all external measurements may be subject to bias and should be used with caution; particularly in geographic studies.

TABLE 2. VARIATION DUE TO SEX IN A SAMPLE OF *BLARINA BREVICAUDA* FROM EAST SPRINGFIELD, ERIE CO., PA.

	Sex	Number in sample N	Range R	Mean $M \pm \sigma_m$	Standard deviation σ	Coefficient of variation V	Mean ♂ minus mean ♀ d	$\frac{d}{\text{standard error of difference}}$ t
Total length	♂	63	106-126	117.20±0.54	4.30±0.38	3.66±0.32	+1.3	1.34
	♀	57	95-128	115.90±0.73	5.49±0.51	4.73±0.44		
Length of tail	♂	64	22-30	26.10±0.22	1.77±0.15	6.78±0.59	+0.8	2.82*
	♀	56	22-29	25.30±0.17	1.34±0.12	5.29±0.49		
Hind foot	♂	64	13-15	14.03±0.08	.65±0.05	4.63±0.40	+0.39	3.44*
	♀	57	12-15	13.64±0.08	.63±0.05	4.61±0.43		
Weight	♂	63	13.0-22.0	16.87±0.21	1.73±0.15	10.25±0.91	+1.29	4.16*
	♀	57	12.5-22.5	15.58±0.23	1.80±0.16	11.51±1.08		
Total length of skull	♂	58	22.4-24.5	23.50±0.04	.50±0.04	2,12±0.19	+0.3	3.49*
	♀	50	21.8-25.0	23.20±0.08	.57±0.06	2.45±0.24		
Cranial breadth	♂	56	11.8-13.4	12.50±0.05	.36±0.03	2.88±0.27	+0.1	1.40
	♀	47	11.7-13.2	12.40±0.05	.36±0.03	2.90±0.29		
Interorbital breadth	♂	63	5.7-6.3	5.95±0.02	.17±0.01	2.85±0.25	+0.2	0.70
	♀	56	5.5-6.6	5.93±0.02	.22±0.02	3.70±0.34		
Maxillary breadth	♂	64	7.0-8.4	7.84±0.03	.24±0.02	3.06±0.26	+0.02	0.47
	♀	57	7.2-8.3	7.82±0.03	.24±0.02	3.06±0.28		
Rostral breadth	♂	64	2.9-3.6	3.15±0.01	.13±0.01	4.12±0.36	+0.01	0.70
	♀	57	2.8-3.4	3.14±0.01	.13±0.01	4.14±0.38		
Total length tooth row	♂	61	10.2-11.3	10.89±0.03	.28±0.02	2.57±0.23	+0.17	4.01*
	♀	56	10.0-11.3	10.72±0.03	.28±0.02	2.54±0.24		
Molar length	♂	64	5.8-6.6	6.26±0.02	.19±0.01	3.03±0.26	+0.05	1.72
	♀	57	5.9-6.6	6.21±0.02	.18±0.01	2.88±0.26		
Foramen magnum width	♂	59	2.9-3.7	3.24±0.02	.19±0.01	5.86±0.53	+0.05	1.75
	♀	48	2.8-3.5	3.19±0.02	.16±0.01	5.01±0.51		
Occipital height	♂	59	6.0-7.2	6.68±0.02	.22±0.02	3.29±0.30	+0.13	4.57*
	♀	50	6.2-6.9	6.55±0.02	.19±0.02	2.90±0.29		

* Indicates a highly significant difference (Probability $<$ 0.01%)

Bias in external measurements

In order to demonstrate the extent of variation due to bias, samples of *Blarina brevicauda* were taken from six localities in the northwestern one-sixth of Pennsylvania.

Measurements of total length, length of tail, length of ear and of hind foot were all taken in the field (using a steel millimeter rule) with the exception of those from East Springfield, Erie Co., Pa. In this case the collector used calipers, which were then read against a steel rule.

The following list groups the localities examined according to possible variations in measuring technique.

Locality	External measurements taken by	Skull measurements taken by	Number of specimens	Month of collection
A. East Springfield, Erie Co.	W. W. Goodpaster		77	Oct.-Nov.
B. State game lands 154, Erie Co.			18	Oct.
C. Benson Swamp, 5 mi. E. of Columbus, Warren Co.	C. L. Gifford		19	Aug.
D. 1.5 mi. N. of Pittsfield, Warren Co.		J. E. Guilday	29	Sept.-Oct.
G. 2 mi. E. of Mars, Butler Co.	J. J. Christian		23	Sept.-Nov.
H. 1.5 mi. N. of Darlington, Beaver Co.			25	July-Aug.

In the graphs, Fig. 4, statistics of three external measurements are presented for each of the six localities.

The shrews from each locality were aged by the method outlined above and only those which fell into age group 2 were used. These samples, therefore, represent shrews of as nearly as possible a comparable age group. Both males and females were included in the samples.

In all the graphs (total length, length of tail, and hind foot) the means for the East Springfield group (locality A) are seen to be significantly lower than the means of localities B, C and D, although the populations are only some fifty miles apart. In each case locality A appears significantly smaller. Localities B, C and D show no significant differences between their respective means, but in length of tail and length of hind foot appear to be significantly greater again than localities G and H. These differences between the means, especially in length of tail (graph 2) and length of hind foot (graph 3) are associated with variation in measuring techniques. The measurements from locality A were taken with calipers and the means of the external measurements were, as a rule, consistently lower than those of the other five localities examined, which were measured directly against a steel rule. Localities B, C and D were measured by a second collector, while localities G and H were measured by a third collector. Skull measurements taken by a single individual

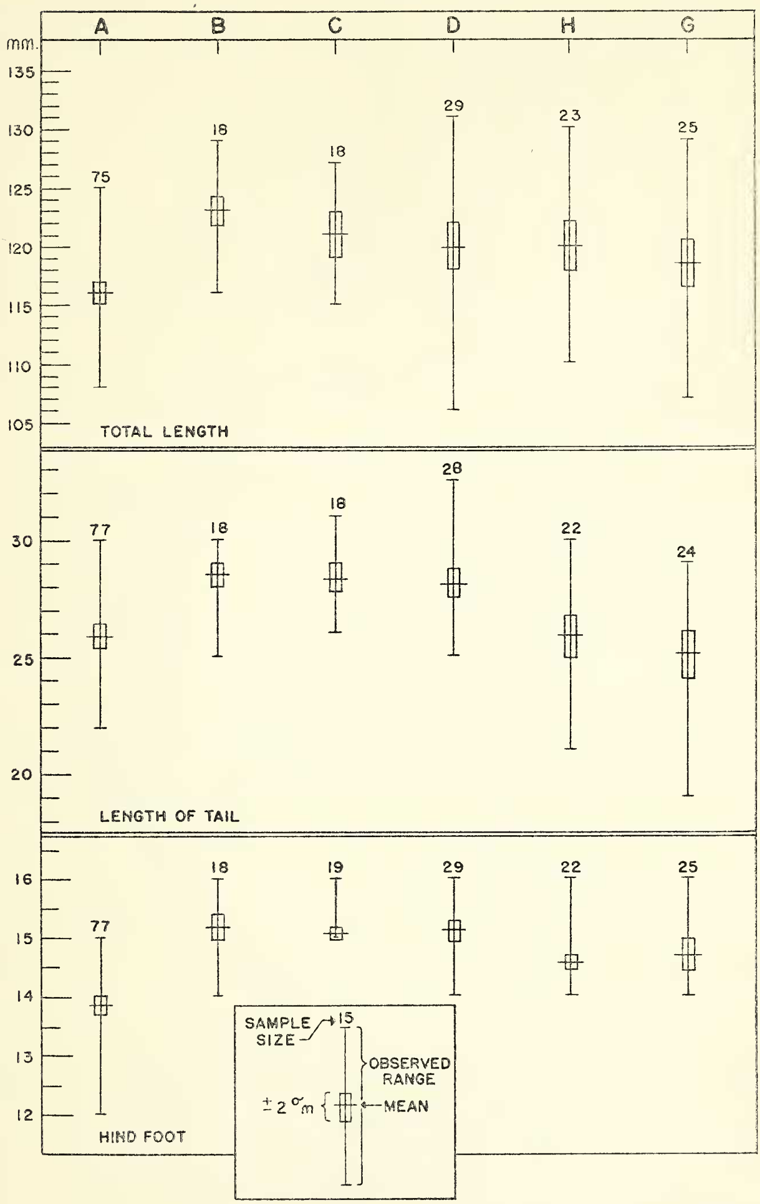

Fig. 4. Comparison of population samples of *Blarina brevicauda* from northwestern one-sixth of Pennsylvania illustrating bias due to collectors' techniques

and involving only one technique do not show this pattern. This makes it appear likely that the observed differences are the result of bias introduced by differing measuring techniques. In this case the collection was accompanied by sufficient data to detect the bias; however, in most cases the magnitude of this significant source of error would not be known. In view of this, external measurements of small mammals should be used with care in comparing populations.

Cranial measurements

The cranial measurements were much more constant than were the external measurements, the coefficients of variation in the former averaging much lower. Several measurements, however, are subject to differences which might affect comparisons of samples, and these should be kept in mind when they are used.

Highly significant (probability 0.01) sexual differences occurred in the following measurements—total length of skull, length of upper tooth row, and occipital height (Table 2). Significant or highly significant age differences occurred in the following measurements—total length of skull, cranial breadth, maxillary breadth, rostral breadth, length of upper molariform row, width of foramen magnum and occipital height (Table 1). Even though these differences are significant, they are slight and might not affect conclusions concerning geographic variation among large samples. However, with the small samples generally available, such differences should be recognized in order to avoid erroneous interpretations as to the taxonomic status of the populations represented.

GEOGRAPHIC VARIATION

In this survey, 1193 skulls of *Blarina brevicauda,* from 26 areas in Pennsylvania (Fig. 5) were aged and measured, using the techniques outlined above. All immature, senile, and obviously abnormal individuals were discarded. In order to have the samples as large as possible the sexes were combined in all cases except weight. The differences are slight and the sex ratio in the samples not markedly biased. Weight is treated for each sex separately because it varies seasonally in response to the reproductive cycle. In southeastern Pennsylvania four of the areas (designated as V, Fig. 5) were lumped into one sample because of the small number of specimens from each. Likewise, two areas (T, Fig. 5) in northeastern Pennsylvania were combined to make one sample. The resulting data are shown by graphs (Fig. 6-14) and in Tables 3-15.

All the graphs except that of weight agree in a common geographic placing of localities. The graph for weight deviates from this plan, in that the localities are placed in a seasonal sequence rather than a geographical one. Each graph is split into three divisions. Localities A through J are all located in western Pennsylvania; localities K through P are located in central Pennsylvania, and localities Q through V in the eastern part of the state. As one progresses from left to right within each of the three divisions one travels from north to south; that is, locality A is in extreme northwestern Pennsylvania, locality J, extreme southwest, etc.

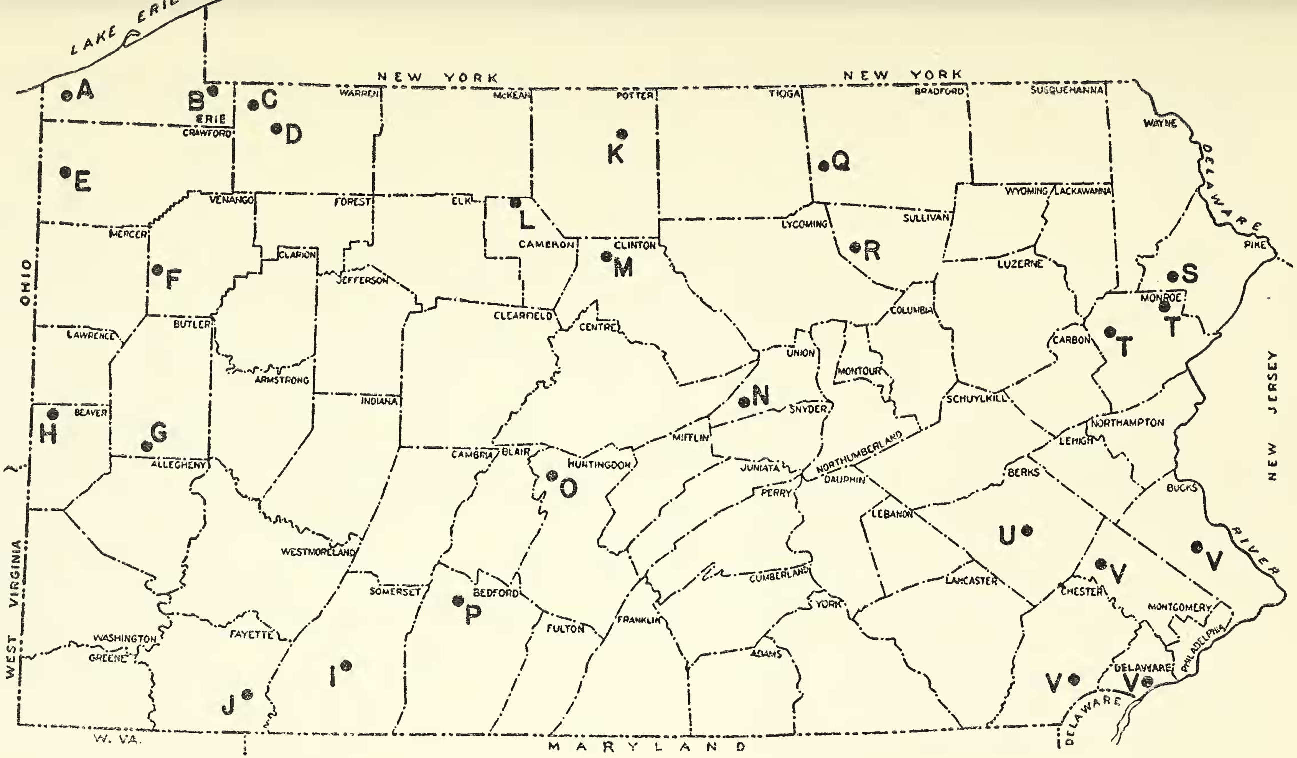

Fig. 5. Outline map of Pennsylvania showing localities from which specimens were studied

A. *Erie Co.,* East Springfield. B. *Erie Co.,* State Game Lands 154, 8 mi. NW. of Corry. C. *Warren Co.,* 5 mi. E. of Columbus. D. *Warren Co.,* 1½ mi. N. of Pittsfield. E. *Crawford Co.,* Pymatuning Swamp, Linesville. F. *Venango Co.,* Sandy Creek, 2 mi. W. of Polk. G. *Butler Co.,* 2 mi. E. of Mars. H. *Beaver Co.,* 1 mi. NE. of Darlington. I. *Somerset Co.,* 4 mi. SW. of Somerset. J. *Fayette Co.,* ½ mi. and ¼ mi. S. of Ohiopyle. K. *Potter Co.,* 4 mi. WSW. of Ulysses. L. *Cameron Co.,* 8 mi. NNW. of Emporium. M. *Clinton Co.,* Tamarack, 9 mi. NNW. of Renovo. N. *Union Co.,* Glen Iron. O. *Huntingdon Co.,* 1 mi. NE. of Spruce Creek. P. *Bedford Co.,* 1 mi. NE. of Osterburg. Q. *Bradford Co.,* 1 mi. N. of Alba. R. *Sullivan Co.,* Ogdonia Creek, 4¼ mi. SSE. of Hillsgrove. S. *Pike Co.,* 5 mi. SE. and 5 mi. E. of Greentown. T. *Monroe Co.,* Buck Hill Falls; 3 mi. N. and 2 mi. N.W. of Pocono Lake. U. *Berks Co.* V. *Bucks, Chester, Montgomery* and *Delaware counties.* See list of specimens examined.

External measurements

Total length (Fig. 6; Table 3) is the most reliable of the external measurements of *Blarina brevicauda;* it is of large enough magnitude so that it is not as readily influenced by bias as are the measurements of hind foot, length of tail and length of ear. The graph, Fig. 6, shows a general decrease in total length from north to south and from west to east. It has been demonstrated (p. 50, 52) that the mean of the sample from area A is low because of bias and it is possible that the same may be true of areas F and M.

The two dimensions, length of tail and length of hind foot, did not follow the trend shown by other measurements, possibly because of the bias introduced by different collectors. The sample statistics are shown in Fig. 7-8, and Tables 4-5.

A valid comparison of weights, particularly in this case, can not be made because of variation introduced by such factors as reproductive status, time of year collected, time of day collected, time elapsed since death, sex and age. Within Pennsylvania, no significant correlation can be obtained between weight and geography. Any geographic variation present is obscured by the operation of extrinsic factors, which can not be eliminated without a prohibitive amount of labor on the part of the collector.

The weight of the female *Blarina* studied can, however, be correlated with the time of the year the samples were collected (Table 6, Fig. 9). The weights of the males, although fluctuating greatly, appeared to follow no consistent pattern. Collections were compared which were made from April through November. The weights of the females dropped from a peak in April, May and June, at which time female weight equaled or exceeded male weight, presumably in response to reproduction, to a low from August through November, when female weight averaged less than that of the males. There is one exception, area C (August-October) where the females slightly exceeded the males in weight.

Evidently the influence of the reproductive cycles has a measurable effect upon the weight of female *Blarina,* but produces no effect, or one that is slight enough to be overshadowed by other effects, in the males.

In the light of the great influence exerted by collecting bias, external measurements seemingly have slight value in a study of geographic variation in *Blarina,* unless the entire series studied is measured by one individual, using one technique and the same instruments throughout, or unless allowance can be made for this source of error. Variations due to differing techniques of mensuration can, and in some cases do, overshadow any true variation present.

Cranial measurements

The cranial measurements of the specimens examined appear to fall into a definite pattern. An east-west cline is clearly demonstrable both statistically and subjectively (Tables 7-15; Fig. 10-14). *Blarina* crania from northwestern Pennsylvania were consistently larger in five of the nine cranial measurements considered. These measurements exhibited some degree of local, apparently random, variation, but when viewed in their entirety they decrease in size towards the east and southeast. The crania diminished in total length of skull, cranial breadth, maxillary breadth, length of tooth row, and rostral breadth. The length of the upper molar series did not follow the general trend but appeared to vary at random throughout the area. The length of the unicuspid series, however, diminished steadily toward the southeast. Width of foramen magnum, interorbital breadth and cranial height showed no apparent clinal variation. In addi-

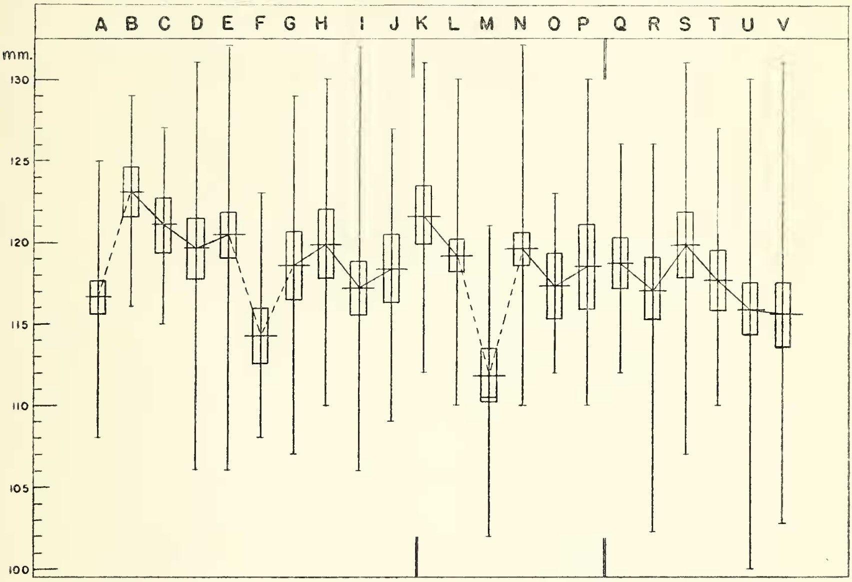

Fig. 6. Variation in total length of *Blarina brevicauda*

TABLE 3. VARIATION IN TOTAL LENGTH OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA. (See Fig. 6)

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	75	116.66±0.49	4.30	3.68	108-125	L	48	119.29±0.76	5.25	4.40	110-130
B	18	123.05±0.72	3.06	2.48	116-129	M	22	111.81±1.24	5.83	5.21	102-121
C	18	121.10±0.89	3.80	3.13	115-127	N	15	119.66±0.50	1.95	1.63	110-132
D	29	119.72±0.95	5.13	4.28	106-131	O	13	117.30±1.00	3.61	3.08	112-123
E	56	120.50±0.73	5.44	4.51	106-132	P	18	118.50±1.36	5.76	4.86	110-130
F	22	114.40±0.86	4.05	3.54	108-123	Q	26	118.76±0.75	3.87	3.85	112-126
G	25	118.64±1.12	5.60	4.71	107-129	R	22	117.04±1.17	5.47	4.67	104-126
H	23	119.91±1.11	5.35	4.46	110-130	S	31	119.80±1.05	5.87	4.89	107-131
I	38	117.24±0.84	5.20	4.43	106-132	T	29	117.72±0.92	4.94	5.19	110-127
J	19	118.47±1.08	4.73	3.99	109-127	U	54	115.88±0.84	6.15	5.31	100-130
K	28	121.71±0.92	4.90	4.02	115-131	V	39	115.56±0.97	6.09	5.27	103-131

tion, the crania in the eastern portion of the state appeared more delicate in general appearance, less angular and rugged. The amount of pigment on the teeth decreased in intensity and the percentage of occurrence of the prominent hook-shaped maxillary processes became progressively less towards the east.

Pennsylvania, according to the most recent taxonomic work on *Blarina* (Bole and Moulthrop, 1942), falls within the range of *Blarina brevicauda kirtlandi* Bole and Moulthrop, with intergradation in the northeastern portion of the state approaching *Blarina brevicauda talpoides* (Gapper). The latter is characterized as being a larger race of *Blarina* and if this

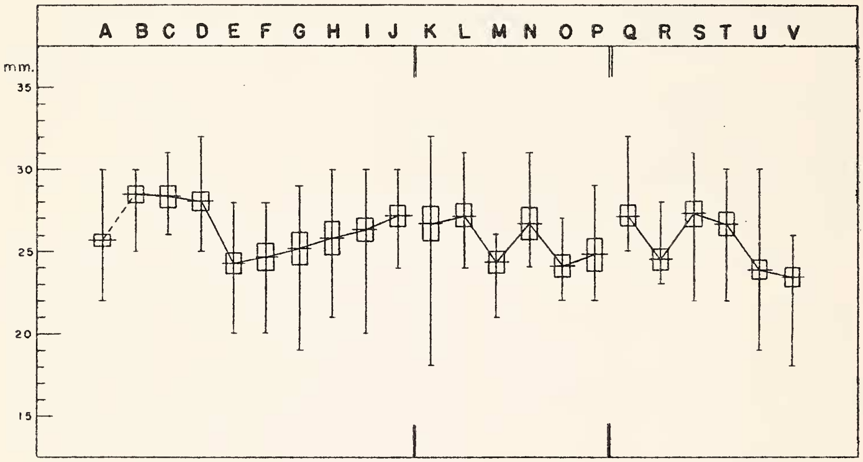

Fig. 7. Variation in length of tail of *Blarina brevicauda*

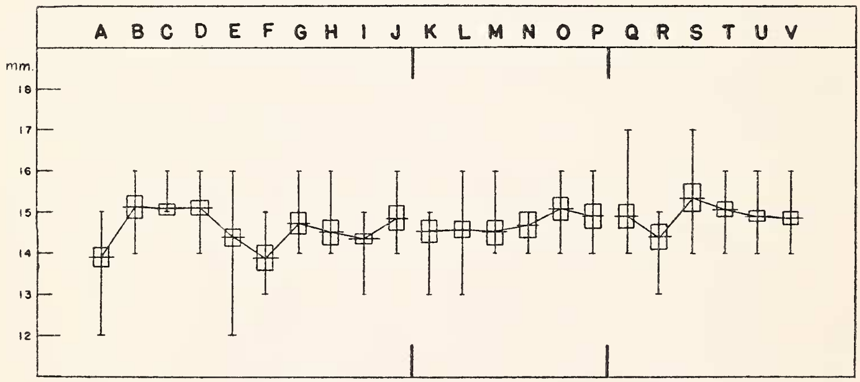

Fig. 8. Variation in hind foot of *Blarina brevicauda*

is true, any intergradation should be towards increasing size in the northeastern portion of the state. This is not the case. The animals become smaller in the east, reaching the minimum size in southeastern Pennsylvania. This would seem to cast some doubt on the present taxonomic status of *Blarina,* so far as Pennsylvania is concerned. Possibly this condition occurs farther north and east, beyond the limits of the state (my data furnish no evidence on this point), but not within the state itself.

From an inspection of the graphs for the various measurements (Fig. 10-14), non-clinal variation may be seen superimposed upon the clinal pattern. Examination of a few scattered localities may, therefore, give a misleading impression of the true picture. If these random variations occur in such a ubiquitous form as *Blarina* which exhibits no pronounced degree of ecological or geographical isolation within the area studied, they may become a problem in the taxonomic interpretation of other species which respond more readily to isolating mechanisms. This demonstrates the necessity for adequate sampling in studies of geographical variation. For example, a sample of 34 shrews from Sandy Creek, Venango County, Pa., locality F on the graphs, appears to be significantly different

TABLE 4. VARIATION IN LENGTH OF TAIL OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA. (See Fig. 7)

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	77	25.74±0.19	1.70	6.60	22-30	L	48	27.16±0.26	1.82	6.70	24-31
B	18	28.50±0.25	1.54	5.43	25-30	M	23	24.48±0.30	1.44	5.88	21-26
C	18	28.30±0.35	1.50	5.30	26-31	N	15	26.66±0.51	1.97	7.36	24-31
D	28	28.10±0.32	1.74	6.19	25-32	O	13	24.07±0.37	1.33	5.52	22-27
E	55	24.31±0.26	1.90	7.81	20-28	P	18	24.88±0.48	2.05	8.24	22-29
F	22	24.68±0.44	2.09	8.47	20-28	Q	25	27.20±0.34	1.74	6.39	25-32
G	24	25.12±0.52	2.58	10.27	19-29	R	22	24.54±0.30	1.41	5.74	23-28
H	22	25.86±0.47	2.22	8.58	21-30	S	31	27.32±0.40	2.23	8.16	22-31
I	38	26.31±0.35	2.22	8.43	20-30	T	29	26.58±0.44	2.38	8.95	22-30
J	19	27.21±0.35	1.52	5.59	24-30	U	54	23.88±0.28	2.05	8.58	19-30
K	28	26.71±0.47	2.49	9.32	18-32	V	39	23.48±0.31	1.96	8.35	18-26

TABLE 5. VARIATION IN HIND FOOT OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA. (See Fig. 8)

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	77	13.85±0.07	0.67	4.83	12-15	L	48	14.58±0.09	0.65	4.46	13-16
B	18	15.16±0.12	0.51	3.36	14-16	M	24	14.54±0.13	0.68	4.68	14-16
C	19	15.05±0.05	0.22	1.46	15-16	N	15	14.66±0.16	0.64	4.36	14-15
D	29	15.13±0.09	0.52	3.43	14-16	O	13	15.07±0.15	0.53	3.52	15-16
E	57	14.40±0.11	0.85	5.90	12-16	P	18	14.94±0.15	0.64	4.28	14-16
F	22	13.90±0.16	0.75	5.39	13-15	Q	26	14.88±0.15	0.79	5.30	14-17
G	25	14.68±0.15	0.73	4.90	14-16	R	22	14.40±0.16	0.77	5.35	13-15
H	22	14.54±0.13	0.65	4.47	14-16	S	31	15.38±0.16	0.92	5.98	14-17
I	38	14.39±0.04	0.26	1.80	13-15	T	29	15.07±0.09	0.48	3.18	14-16
J	19	14.84±0.12	0.54	3.64	14-16	U	56	14.91±0.07	0.53	3.55	14-16
K	28	14.57±0.12	0.65	4.46	13-15	V	39	14.85±0.07	0.47	3.16	14-16

Fig. 9. Variation in weight of *Blarina brevicauda*

TABLE 6. VARIATION IN WEIGHT OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA. (See Fig. 9)

Loc.	Sex	N	M	σ	V	Range	Season
R	♂	13	17.61±0.58	2.10±0.41	11.92±2.34	14.0-22.0	Apr.-May
	♀	9	17.33±1.08	3.25±0.76	18.75±4.42	12.0-21.0	
P	♂	8	17.69±1.11	3.15±0.79	17.81±4.45	13.5-20.5	May
	♀	10	18.25±0.79	2.51±0.56	13.75±3.07	15.5-23.5	
N	♂	7	15.85±1.08	2.88±0.76	18.17±4.86	12.0-21.0	May-June
	♀	8	17.87±1.04	2.94±0.73	16.45±4.11	13.0-22.0	
O	♂	4	17.00±0.81	1.27±0.45	7.47±2.64	15.5-18.5	June
	♀	9	16.93±0.47	1.34±	7.91±1.98	15.5-18.5	
M	♂	12	17.16±0.59	2.03±0.41	11.83±2.41	13.0-20.0	July-Aug.
	♀	12	16.75±0.59	2.04±0.42	12.18±2.49	14.0-22.0	
D	♂	14	19.21±0.42	1.57±0.30	8.17±1.54	17.0-22.0	Aug.
	♀	15	17.40±0.48	1.88±0.34	10.80±1.97	14.0-21.0	
G	♂	8	16.50±0.54	1.53±0.38	7.63±1.91	15.0-19.0	Aug.
	♀	10	15.96±0.40	1.26±0.28	7.89±1.76	13.5-18.0	
L	♂	27	15.70±0.37	1.93±0.26	12.29±1.67	12.0-21.0	Aug.-Sept.
	♀	20	15.25±0.37	1.67±0.26	10.95±1.73	12.0-19.0	
S	♂	14	16.93±0.40	1.56±0.28	9.21±1.68	14.5-20.5	Aug.-Sept.
	♀	16	15.46±0.41	1.66±0.29	10.74±1.90	13.0-18.5	
C	♂	11	17.09±0.47	1.57±0.33	9.19±1.96	15.0-20.0	Aug.-Oct.
	♀	11	16.44±0.71	2.14±0.50	13.02±3.07	13.0-21.0	
J	♂	9	16.77±0.36	1.07±0.25	6.38±1.50	15.0-18.0	Oct.
	♀	10	14.80±0.33	1.05±0.23	7.09±1.58	13.5-16.5	
Q	♂	12	17.33±0.33	1.16±0.24	6.69±1.36	15.0-21.0	Oct.
	♀	14	15.28±0.57	2.13±0.40	13.94±2.63	12.0-18.0	
H	♂	14	17.89±0.45	1.67±0.31	9.33±1.76	15.0-20.0	Sept.-Nov.
	♀	9	16.00±0.46	1.37±0.32	8.56±2.02	13.5-18.0	
A	♂	63	16.87±0.21	1.73±0.15	10.25±0.91	13.0-22.0	Oct.-Nov.
	♀	57	15.58±0.23	1.80±0.16	11.51±1.08	12.5-22.5	

from the surrounding populations in many of the characters studied. Groups such as this have at times been described as new taxonomic forms by some workers. It is very improbable, if these differences are assumed to be heritable, that they represent more than a transitory condition of little evolutionary significance. They may, however, be a response to some unrecognized local environmental factor which will continue to separate this group even further from the original stock. Again, they may be non-genetic in nature, a reflection of collecting bias, or inadequate sampling. A formal recognition of these minor variations, even if they can readily be separated from the surrounding populations, would seem to call for extreme caution. Because of our inability to assign cause for effect, or

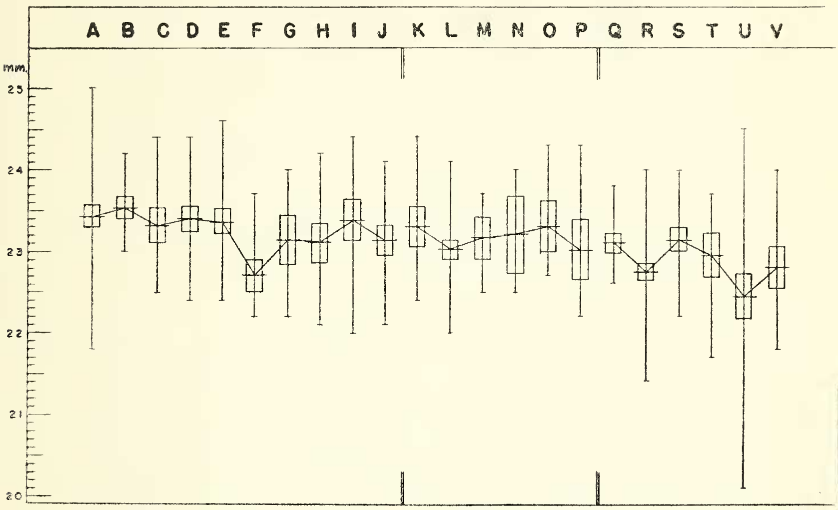

Fig. 10. Variation in total length of skull of *Blarina brevicauda*

TABLE 7. VARIATION IN TOTAL LENGTH OF SKULL OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA. (See Fig. 10)

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	73	23.44±0.06	0.57	2.43	21.8-25.0	L	49	23.01±0.06	0.46	1.99	22.0-24.1
B	18	23.54±0.07	0.33	1.40	23.0-24.2	M	20	23.16±0.13	0.60	2.59	22.5-23.7
C	19	23.31±0.11	0.50	2.14	22.5-24.4	N	14	23.20±0.24	0.92	3.96	22.5-24.0
D	28	23.40±0.08	0.47	2.00	22.4-24.4	O	13	23.32±0.16	0.59	2.53	22.7-24.3
E	57	23.37±0.07	0.53	2.27	22.4-24.6	P	18	23.02±0.19	0.81	3.52	22.2-24.3
F	20	22.77±0.10	0.44	1.93	22.2-23.7	Q	26	23.10±0.06	0.30	1.29	22.6-23.8
G	24	23.14±0.15	0.77	3.32	22.2-24.0	R	21	22.75±0.05	0.23	1.01	21.4-24.0
H	20	23.11±0.12	0.57	2.42	22.1-24.2	S	30	23.13±0.07	0.38	1.64	22.2-24.0
I	37	23.39±0.13	0.82	3.50	22.0-24.4	T	24	22.94±0.14	0.68	2.96	21.7-23.7
J	19	23.13±0.14	0.59	2.56	22.1-24.1	U	54	22.45±0.14	1.01	4.50	20.1-24.5
K	28	23.30±0.12	0.64	2.75	22.4-24.4	V	32	22.81±0.13	0.75	3.28	21.8-24.0

weigh the relative effects of environment on one hand and heredity on the other, raising such a group to subspecific status should not be undertaken rashly, but only after careful weighing of all of the evidence available. The informal recognition of a local race to aid in the study and clarification of the factors involved in its formation is one thing, but formally describing it as a well defined entity in a phylogenetic classifi-

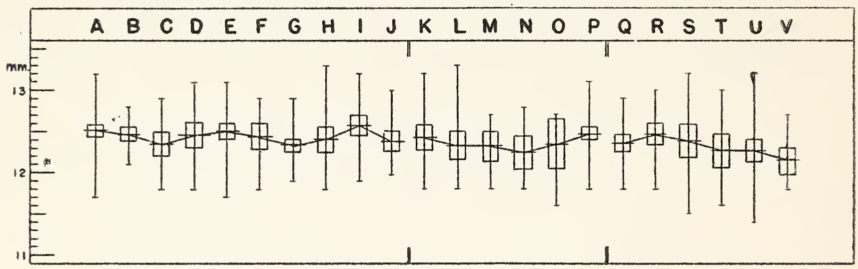

Fig. 11. Variation in cranial breadth of *Blarina brevicauda*

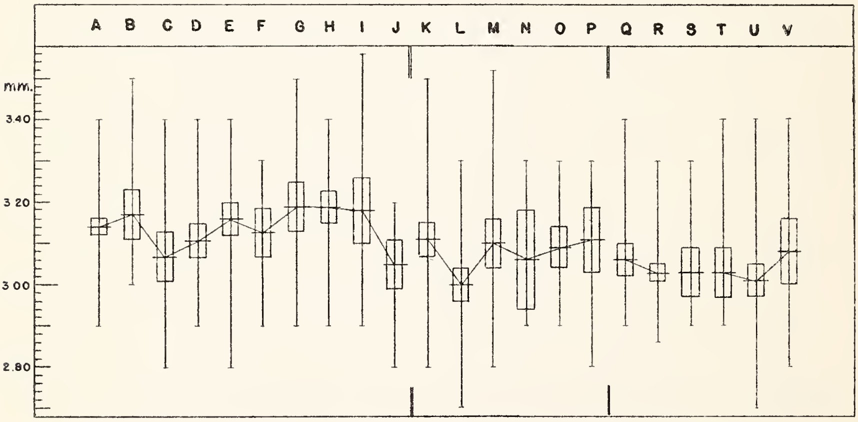

Fig. 12. Variation in rostral breadth of *Blarina brevicauda*

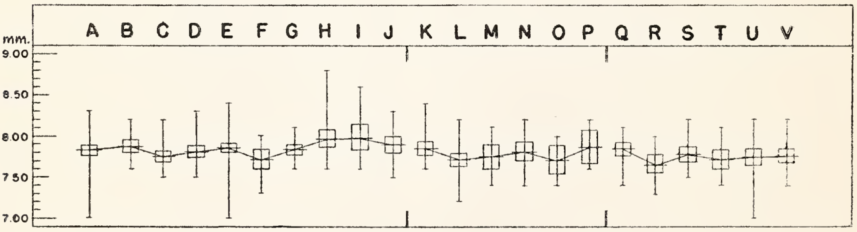

Fig. 13. Variation in maxillary breadth of *Blarina brevicauda*

cation is quite another. One of the basic goals of the study of evolution at any taxonomic level should be the recognition of the forces acting

TABLE 8. VARIATION IN CRANIAL BREADTH OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA. (See Fig. 11)

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	72	12.51±0.03	0.33	2.63	11.7-13.2	L	46	12.32±0.08	0.54	4.38	11.8-13.3
B	17	12.47±0.04	0.20	1.60	12.1-12.8	M	21	12.32±0.09	0.41	3.33	11.8-12.7
C	19	12.36±0.07	0.33	2.66	11.8-12.9	N	15	12.23±0.11	0.44	3.60	11.8-12.8
D	29	12.46±0.08	0.43	3.45	11.8-13.1	O	13	12.34±0.16	0.58	4.70	11.6-12.7
E	54	12.50±0.04	0.30	2.40	11.7-13.1	P	17	12.47±0.03	0.14	1.12	11.8-13.1
F	20	12.44±0.08	0.37	2.97	11.8-12.9	Q	24	12.37±0.06	0.32	2.58	11.8-12.9
G	24	12.33±0.04	0.24	1.94	11.9-12.9	R	20	12.47±0.07	0.33	2.65	11.8-13.0
H	20	12.42±0.08	0.38	3.05	11.8-13.3	S	28	12.39±0.10	0.56	4.52	11.5-13.2
I	37	12.58±0.06	0.38	3.02	11.9-13.2	T	21	12.26±0.11	0.51	4.16	11.6-13.0
J	20	12.39±0.06	0.26	2.09	12.0-13.0	U	50	12.27±0.07	0.47	3.83	11.4-13.2
K	26	12.42±0.08	0.40	3.22	11.8-13.2	V	32	12.14±0.08	0.48	3.95	11.8-12.7

TABLE 9. VARIATION IN ROSTRAL BREADTH OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA. (See Fig 12)

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	77	3.14±0.01	0.13	4.14	2.9-3.4	L	48	3.00±0.02	0.14	4.66	2.7-3.3
B	18	3.17±0.03	0.13	4.10	3.0-3.5	M	23	3.10±0.03	0.14	4.52	2.8-3.6
C	19	3.07±0.03	0.16	5.21	2.8-3.4	N	15	3.06±0.06	0.24	7.84	2.9-3.3
D	29	3.11±0.02	0.14	4.50	2.9-3.4	O	13	3.09±0.05	0.17	5.50	2.9-3.3
E	55	3.16±0.02	0.17	5.38	2.8-3.4	P	18	3.11±0.04	0.17	5.47	2.8-3.3
F	22	3.13±0.03	0.14	4.47	2.9-3.3	Q	26	3.06±0.02	0.12	3.92	2.9-3.4
G	25	3.19±0.03	0.15	4.70	2.9-3.5	R	22	3.03±0.01	0.05	1.07	2.8-3.3
H	23	3.19±0.02	0.11	3.47	2.9-3.4	S	31	3.03±0.03	0.17	5.61	2.9-3.3
I	38	3.18±0.04	0.26	8.17	2.9-3.8	T	29	3.03±0.03	0.14	4.62	2.8-3.4
J	19	3.05±0.03	0.14	4.59	2.8-3.2	U	56	3.01±0.02	0.14	4.65	2.7-3.3
K	28	3.11±0.02	0.10	3.21	2.8-3.5	V	36	3.08±0.04	0.24	7.79	2.8-3.4

TABLE 10. VARIATION IN MAXILLARY BREADTH OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA. (See Fig. 13)

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	77	7.84±0.02	0.22	2.80	7.0-8.3	L	48	7.71±0.03	0.24	3.11	7.2-8.2
B	18	7.88±0.03	0.14	1.77	7.6-8.2	M	24	7.75±0.08	0.40	5.16	7.4-8.1
C	19	7.77±0.03	0.17	2.11	7.5-8.2	N	15	7.82±0.06	0.25	3.19	7.4-8.2
D	29	7.82±0.03	0.19	2.42	7.5-8.3	O	13	7.71±0.09	0.33	4.28	7.4-8.0
E	56	7.87±0.02	0.14	1.78	7.0-8.4	P	18	7.87±0.10	0.41	5.21	7.6-8.2
F	22	7.71±0.06	0.30	3.89	7.3-8.0	Q	26	7.86±0.04	0.23	2.93	7.4-8.1
G	25	7.84±0.03	0.14	1.78	7.6-8.1	R	22	7.66±0.05	0.22	2.87	7.3-8.0
H	23	7.98±0.05	0.28	3.50	7.6-8.8	S	30	7.79±0.04	0.22	2.82	7.5-8.2
I	38	7.99±0.08	0.53	6.63	7.6-8.6	T	28	7.72±0.06	0.31	4.01	7.4-8.1
J	19	7.90±0.05	0.22	2.78	7.5-8.3	U	56	7.75±0.05	0.34	4.39	7.0-8.2
K	28	7.85±0.04	0.20	2.55	7.6-8.4	V	37	7.77±0.04	0.22	2.83	7.4-8.2

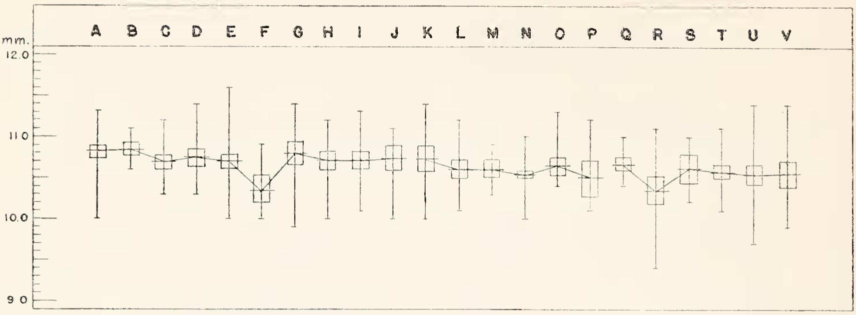

Fig. 14. Variation in length of upper tooth row of *Blarina brevicauda*

TABLE 11. VARIATION IN LENGTH OF UPPER TOOTH ROW OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA. (See Fig. 14)

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	75	10.83±0.03	0.31	2.86	10.0-11.3	L	49	10.62±0.06	0.46	4.33	10.1-11.2
B	18	10.86±0.04	0.17	1.56	10.6-11.1	M	23	10.62±0.05	0.24	2.26	10.3-10.9
C	18	10.70±0.04	0.19	1.77	10.3-11.2	N	15	10.56±0.02	0.07	.66	10.0-11.0
D	29	10.76±0.05	0.28	2.60	10.3-11.4	O	13	10.67±0.04	0.14	1.31	10.4-11.3
E	57	10.71±0.04	0.31	2.89	10.0-11.6	P	18	10.50±0.11	0.47	4.48	10.1-11.2
F	22	10.38±0.09	0.42	4.05	10.0-10.9	Q	26	10.68±0.04	0.20	1.87	10.4-11.0
G	25	10.81±0.07	0.35	3.23	9.9-11.4	R	22	10.37±0.09	0.44	4.24	9.4-11.1
H	23	10.72±0.06	0.30	2.79	10.0-11.2	S	31	10.62±0.09	0.50	4.71	10.2-11.0
I	38	10.71±0.05	0.33	3.08	10.1-11.3	T	29	10.59±0.04	0.22	2.08	10.1-11.1
J	20	10.73±0.09	0.41	3.82	10.0-11.1	U	53	10.54±0.06	0.47	4.46	9.7-11.4
K	27	10.74±0.08	0.42	3.91	10.0-11.4	V	35	10.57±0.09	0.54	5.11	9.9-11.4

TABLE 12. VARIATION IN WIDTH OF FORAMEN MAGNUM OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	74	3.20±0.02	0.16	5.00	2.8-3.6	L	47	3.23±0.02	0.14	4.33	2.9-3.7
B	18	3.34±0.03	0.15	4.49	3.0-3.6	M	19	3.32±0.04	0.17	5.12	3.0-3.5
C	18	3.32±0.03	0.16	4.81	3.0-3.6	N	14	3.25±0.05	0.17	5.23	2.9-3.5
D	29	3.33±0.03	0.17	5.10	3.1-3.7	O	13	3.27±0.08	0.28	8.56	2.9-3.5
E	57	3.25±0.03	0.22	6.77	2.8-3.5	P	18	3.21±0.04	0.17	5.29	3.0-3.5
F	19	3.24±0.06	0.26	8.02	3.0-3.5	Q	25	3.27±0.03	0.15	4.58	3.0-3.5
G	24	3.24±0.03	0.17	5.24	2.9-3.6	R	21	3.26±0.05	0.24	7.36	3.0-3.8
H	20	3.27±0.04	0.20	6.11	2.9-3.6	S	27	3.28±0.05	0.24	7.32	2.9-3.5
I	36	3.26±0.04	0.28	8.58	2.9-3.6	T	24	3.24±0.03	0.17	5.25	2.9-3.6
J	20	3.30±0.05	0.24	7.27	3.0-3.6	U	52	3.21±0.03	0.24	7.48	3.0-3.5
K	26	3.30±0.04	0.22	6.66	3.0-3.7	V	36	3.24±0.04	0.26	8.02	3.0-3.5

on the organism; not the relatively unproductive procedure of naming new forms *ad infinitum* with little thought as to what lies behind them.

In order to work within any group the subgroups must, of necessity, have some sort of tag on them; some method of designation must be employed for practical reasons, if for no other. The admission of a group to a phylogenetic classification carries with it many implications concerning the genetic composition of that group. Morphological differences are assumed, on good grounds in most cases, to be expressions of differing genetic make-ups. Every variation, which may conceivably have any bearing on the problem at hand should be recognized of course. But, without a thorough knowledge based upon adequate samples and a comprehensive knowledge of variation within the larger category of which they are a part, minor secondary fluctuations may be brought to the foreground; and the primary trends lying behind them may be overlooked. The forest soon becomes lost in the trees.

TABLE 13. VARIATION IN INTERORBITAL BREADTH OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	77	5.95±0.02	0.19	3.19	5.7-6.6	L	48	5.86±0.05	0.32	5.46	5.3-6.5
B	17	5.98±0.04	0.17	2.84	5.8-6.2	M	24	5.92±0.04	0.22	3.72	5.5-6.5
C	18	5.93±0.04	0.19	3.20	5.6-6.2	N	15	5.91±0.06	0.23	3.89	5.7-6.1
D	29	5.90±0.05	0.25	4.24	5.7-6.4	O	13	5.89±0.08	0.28	4.75	5.3-6.2
E	57	5.93±0.04	0.31	5.23	5.5-6.3	P	17	5.92±0.04	0.17	2.87	5.5-6.6
F	21	5.86±0.05	0.24	4.09	5.6-6.3	Q	26	5.98±0.04	0.19	3.17	5.5-6.3
G	25	5.99±0.04	0.22	3.67	5.7-6.4	R	22	5.90±0.06	0.27	4.58	5.6-6.1
H	23	6.03±0.03	0.19	3.15	5.8-6.5	S	31	5.94±0.05	0.30	5.05	5.6-6.4
I	38	5.97±0.03	0.22	3.68	5.5-6.4	T	30	5.88±0.04	0.20	3.40	5.4-6.2
J	19	5.93±0.07	0.32	5.39	5.5-6.1	U	56	5.80±0.03	0.22	3.79	5.3-6.8
K	28	6.04±0.03	0.14	2.32	5.7-6.5	V	37	5.84±0.04	0.22	3.77	5.5-6.2

TABLE 14. VARIATION IN LENGTH OF UPPER MOLARIFORM SERIES OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	77	6.25±0.02	0.19	3.04	5.8-6.6	L	49	6.16±0.01	0.10	1.62	5.9-6.5
B	18	6.27±0.03	0.16	2.55	6.0-6.6	M	23	6.23±0.05	0.26	4.17	5.9-6.4
C	18	6.16±0.02	0.10	1.62	5.9-6.3	N	15	6.23±0.04	0.17	2.73	6.0-6.5
D	29	6.24±0.02	0.14	2.24	6.0-6.5	O	13	6.26±0.10	0.36	5.75	6.1-6.5
E	57	6.19±0.04	0.32	5.17	5.8-6.6	P	18	6.17±0.06	0.24	3.89	5.8-6.5
F	22	6.06±0.05	0.26	4.29	5.8-6.4	Q	26	6.23±0.06	0.29	4.65	5.9-6.6
G	25	6.22±0.03	0.21	3.37	5.9-6.7	R	22	6.09±0.07	0.33	5.41	5.5-6.5
H	23	6.25±0.03	0.19	2.14	5.8-6.6	S	31	6.20±0.02	0.10	1.61	5.9-6.4
I	38	6.24±0.04	0.30	4.80	5.9-6.5	T	30	6.23±0.04	0.24	3.85	6.0-6.5
J	20	6.30±0.06	0.26	4.13	6.1-6.5	U	53	6.19±0.04	0.30	4.85	5.7-6.6
K	27	6.19±0.06	0.33	5.33	5.9-6.5	V	37	6.24±0.04	0.26	4.17	6.0-6.6

TABLE 15. VARIATION IN CRANIAL HEIGHT OF *BLARINA BREVICAUDA* FROM VARIOUS LOCALITIES IN PENNSYLVANIA

Station	N	M	σ	V	R	Station	N	M	σ	V	R
A	75	6.57±0.02	0.18	2.73	6.2-6.9	L	47	6.42±0.04	0.28	4.36	6.1-6.8
B	18	6.55±0.04	0.18	2.74	6.1-6.8	M	22	6.55±0.04	0.17	2.59	6.1-6.9
C	19	6.56±0.04	0.19	2.89	6.3-7.0	N	14	6.56±0.04	0.16	2.44	6.2-6.8
D	28	6.59±0.03	0.18	2.73	6.2-6.9	O	13	6.57±0.10	0.36	5.48	6.1-6.8
E	56	6.46±0.04	0.10	4.95	5.9-7.0	P	18	6.52±0.06	0.26	3.98	6.1-7.0
F	19	6.25±0.06	0.26	4.16	5.9-6.6	Q	26	6.50±0.05	0.26	4.00	6.1-6.7
G	24	6.55±0.03	0.19	2.90	6.0-6.9	R	20	6.47±0.06	0.28	4.32	6.3-6.7
H	21	6.52±0.03	0.17	2.60	6.2-6.8	S	27	6.53±0.03	0.14	2.14	6.3-6.8
I	35	6.62±0.06	0.36	5.43	6.4-6.9	T	24	6.32±0.03	0.17	2.69	6.1-6.6
J	20	6.44±0.07	0.32	4.97	5.9-6.8	U	53	6.42±0.04	0.31	4.83	6.0-6.9
K	28	6.54±0.04	0.24	3.67	6.1-6.9	V	35	6.32±0.05	0.30	4.75	6.0-6.6

CONCLUSIONS

The range of *Blarina brevicauda,* of which the state of Pennsylvania comprises only a relatively small portion, extends across that portion of the United States and southern Canada east of the Great Plains proper. The state encompasses a rectangular area, 300 miles from east to west and 180 miles from north to south. Pennsylvania traverses seven physiographic provinces (Fenneman, 1938). These are (1) Coastal Plain Province, (2) Piedmont Province, (3) Blue Ridge Province, (4) Ridge and Valley Province, (5) Appalachian Plateau Province, (6) New England Province, and (7) a small section of the Central Lowland east of the Mississippi in extreme northwestern Pennsylvania bordering Lake Erie. Superimposed upon, but uncorrelated with, this involved physiographic situation *Blarina brevicauda* presents a relatively simple picture of clinal variation. It becomes smaller in overall dimensions and exhibits slight morphological differences in the crania towards the east.

The Appalachian mountain system, as it extends northward from Georgia through Pennsylvania, becomes progressively less efficient in its ability to isolate cryophilic forms. From an altitude of 6711 feet at Mt. Mitchell, North Carolina, the system declines northwards through Virginia and Maryland into the South Mountain range of southeastern Pennsylvania, scarcely 2000 feet in elevation. Similarly, the high plateau of the Catskills in southern New York, which reaches 4000 feet in places, slopes southward to the Delaware River and forms, in Pennsylvania, the Pocono Plateau of only 2000 feet elevation (Lesley, 1885). Ortman (1913, p. 347-348) points out the interesting fact that as one progresses north along the mountains the head-waters of the eastern draining streams push farther and farther to the west. He says, "Coming to the Potomac drainage, we observe that this river has cut clear across the mountains, and has reached in northeastern West Virginia and in western Maryland, the western [sic] boundary of the Allegheny Plateau, Allegheny Front, and at one point has even cut through this and encroached upon the Allegheny

Plateau . . . The Susquehanna in Pennsylvania has progressed farthest in the capture of the western streams. It has not only cut clear across the mountains, but has also invaded a large section of the plateau, which originally drained to the westward".

Thus in Pennsylvania the Appalachians break down; divides are lowered; the ranges have been completely captured by eastern drainage; and ecological differences between physiographic provinces, have become less efficient in limiting the distribution of mammals. This becomes apparent when one examines the ranges of such mammals as *Parascalops breweri, Sorex cinereus, Sorex fumeus* and *Sorex palustris,* which in the south are restricted to the mountain provinces (Burt, 1952). The Appalachian Mountains provide a southern extension of the habitat to which these forms are adapted, but in the north their ranges fan out both east and west as interprovincial limiting factors become less intense.

Straddling, as it does, the Appalachian mountain system at a point where major ecological areas begin to break down and function less efficiently as zoogeographic barriers, the fauna of Pennsylvania might be expected to demonstrate a condition of intergradation between its western and eastern facies. This is apparently reflected in the variation exhibited by *Blarina brevicauda* within Pennsylvania.

The Southern Appalachian mountain system affords suitable habitat for the large northern forms of *Blarina* which extend southward via the mountains, pushing a tongue deep into the territory of the smaller southern form, *Blarina b. carolinensis,* which surrounds the mountains on three sides. *Blarina b. carolinensis* is a form of the southern lowlands, the lower Mississippi Valley, west to the Great Plains, and the southeastern seaboard north to Virginia, but apparently has not been successful in the mountains proper.

Within Pennsylvania, an east-west cline has been demonstrated in *Blarina.* As one progresses eastward in the state the skulls approach the appearance of those of *Blarina b. carolinensis;* the samples from the southeastern sector of the state are the extreme of the cline as represented in Pennsylvania.

Assuming this cline to be primarily genetic in origin, it would seem to demonstrate intergradation between the population of *Blarina brevicauda* to the west with that of the smaller southern lowland form, north of the Appalachian barrier. Merriam (1895), and Bole and Moulthrop (1942), point out that *Blarina* appear to become smaller as one progresses from Ontario southward, east of the Great Lakes. This again would seem to be in the direction of *carolinensis,* only in this case the diminution in size is from north to south rather than from west to east.

This hypothesis, however, is based solely upon the indirect evidence of Pennsylvania specimens, and is offered as one possible interpretation. The area examined is small, and therefore any attempt to relate it to other areas can be hazardous. Further taxonomic research on *Blarina brevicauda* is needed to clarify the Post-Pleistocene evolution within the species.

LIST OF SPECIMENS EXAMINED

Specimens from Pennsylvania numbered 1193 distributed as follows: *Beaver Co.,* 1 mi. NE. of Darlington, 40; Bieler Run, 0.5 mi. W. of Bealer Run School, 17; 5 mi. N. of New Galilee, 4; 2 mi. E. of Industry, 7; 1 mi. S. of Rowtown, 8. *Bedford Co.,* 1 mi. NE. of Osterburg, 29. *Berks Co.,* 2 mi. SSE. of Shanesville, 3; 2.25 mi. NW. of Lenhartsville, 5; 0.5 mi. N. of Lenhartsville, 2; 2.5 mi. N. of Shartlesville, 1; 0.25 mi. W. of Moselem, 3; 1 mi. S. of Eckville, 7; 2.5 mi. NNW. of Shartlesville, 1; 4 mi. SW. of Eckville, 2; 2.5 mi. N. of Monocacy, 6; 0.5 mi. N. of Douglassville, 2; 1 mi. SW. of Pine Forge, 2; 3 mi. NE. of Hamburg, 2; 2.5 mi. NW. of Albany, 6; 1 mi. S. of Athol, 1; 1.5 mi. NE. of Monocacy, 1; 1.5 mi. SW. of Weavertown, 3; 0.5 mi. SW. of Athol, 1; 0.5 mi. W. of Athol, 1; 0.5 mi. NE. of Earlville, 1; 1.5 mi. NE. of Scarlets Mill, 4; 2.5 mi. SSE. of Shanesville, 2. *Bradford Co.,* 1 mi. N. of Alba, 31. *Bucks Co.,* 4 mi. NW. of Dublin, 2; 1.5 mi. SW. of Point Pleasant, 3; 1.5 mi. SW. of Dublin, 1; 2 mi. N. of New Britain, 2; 2 mi. NW. of Doylestown, 2; 1.5 mi. N. of Perkasie, 1; 0.5 mi. SE. of Buckingham, 1; 1 mi. S. of New Britain, 2; 1.5 mi. SE. of Dublin, 1; 3 mi. SE. of Furlong, 2; 2 mi. N. of Perkasie, 1; 3 mi. NW. of Ottsville, 2. *Butler Co.,* 2 mi. E. of Mars, 42; 3 mi. E. of Mars, 11; Mars, 1; 2 mi. E. of Middle Lancaster, 10; Thorn Creek, 4 mi. S. of Butler, 19; Thorn Creek, 2 mi. W. of Saxonburg, 10. *Cambria Co.,* Cresson, 21. *Cameron Co.,* Three Mile Run, 8 mi. NNW. of Emporium, 66. *Chester Co.,* 0.75 mi. and 1 mi. E. of Unionville, 12. *Clinton Co.,* Tamarack, 9 mi. NNW. of Renovo, 28. *Crawford Co.,* Pymatuning Swamp, 77. *Delaware Co.,* Tinicum Island, ½ mi. W. of Philadelphia, 2. *Erie Co.,* State Game Lands 154, 22; East Springfield, 121. *Fayette Co.,* 0.5 mi. and 0.25 mi. S. of Ohiopyle, 22. *Huntingdon Co.,* 1 mi. NE. of Spruce Creek, 19. *Jefferson Co.,* 5.5 mi. E. of Sigel, 11; Heath Station, 8 mi. NE. of Sigel, 5. *Lawrence Co.,* 1 mi. S. of McConnells Mills, 17; 4 mi. SW. of New Wilmington, 4; 0.5 mi. N. of McConnells Mills, 8. *McKean Co.,* Sugar Run, 10 mi. SW. of Bradford, 7. *Mercer Co.,* 2.5 mi. W. of Mercer, 36; 12 mi. W. of Mercer, 5; 5 mi. S. of Mercer, 10; 2 mi. N. of Clarks Mills, 3; 3 mi. E. of Sandy Lake, 1. *Monroe Co.,* 3 mi. N., 2 mi. NW. of Pocono Lake, 19; Buck Hill Falls, 15. *Montgomery Co.,* 4 mi. NE. of Pottstown, 6. *Pike Co.,* 5 mi. SE. of Greentown, 21; 5 mi. E. of Greentown, 18. *Potter Co.,* 4 mi. WSW. of Ulysses, 31. *Somerset Co.,* 4 mi. SW. of Somerset, 49. *Sullivan Co.,* Ogdonia Creek, 4.25 mi. SSE. of Hillsgrove, 34. *Union Co.,* Glen Iron, 23. *Venango Co.,* Sandy Creek, 2 mi. W. of Polk, 34; Pecan, 4 mi. S. of Franklin, 2; Sugar Creek, 3 mi. NW. of Franklin, 2; Lower Two Mile Run, 2 mi. E. of Franklin, 5; 4 mi. W. of Franklin, 2; 2 mi. NE. of Franklin, 7; 9 mi. E. of Oil City, 8; 6 mi. E. of Oil City, 5; 6 mi. N. of Oil City, 18; 1 mi. SW. of Utica, 12; 1.5 mi. NE. of Kennerdell, 1; 2 mi. S. of Franklin, 3. *Warren Co.,* Benson Swamp, 5 mi. E. of Columbus, 29; 1.5 mi. N. of Pittsfield, 36; 2 mi. S. of Weldbank, 1; 2.5 mi. N. of Kinzua, 11; Miles Run, 5 mi. NW. of Pittsfield, 9; 5 mi. N. of Pittsfield, 4; 4 mi. SW. of Youngsville, 5; 1 mi. SE. of Garland, 17; 2 mi. N. of Pittsfield, 5; 6 mi. N. of Pittsfield, 6.

SUMMARY

This article presents a method of arriving at the relative age of specimens of *Blarina brevicauda* based upon cranial suture closure.

Males averaged significantly greater than females in total length, length of hind foot, weight, total length of skull and occipital height in a sample of 121 specimens from northwestern Pennsylvania.

Age differences in the samples studied were slight. All immature shrews collected were of essentially adult size. However, significant differences between younger and older specimens were found in weight, total length of skull, cranial height, maxillary breadth, and width of foramen magnum.

External measurements were found to be significantly influenced by personal bias.

A west-east cline is demonstrated for *Blarina brevicauda* in Pennsylvania, shrew crania becoming smaller and less rugged towards the east. It is suggested that this demonstrates intergradation with the smaller Atlantic Coast form, *Blarina brevicauda carolinensis*.

The most recent taxonomic work on the northern races of *Blarina brevicauda* appears to be at variance with the results reported herein, as far as Pennsylvania is concerned, and thus suggests the need for future study.

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